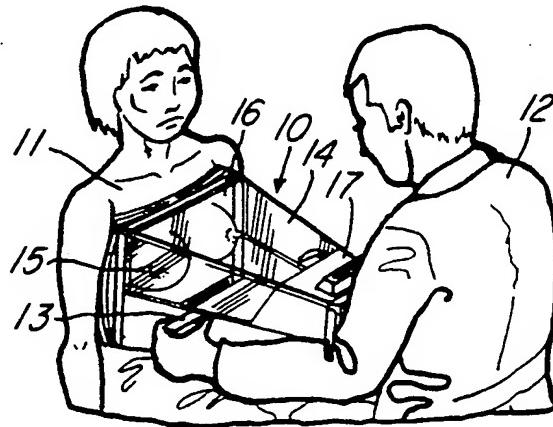


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(54) Title: DEVICE FOR DETECTING, MEASURING AND RECORDING BODY THERMAL EMISSIVITY



(57) Abstract

A portable unit includes a hand supported housing defining a chamber (20) and having a larger end portion closed by a removable thermoresponsive flexible screen (16) carrying a layer of liquid crystals. The smaller end portion of the housing supports a camera (17) having a lens (21) projecting into the chamber which receives pressurized air through a passage or duct (37). The housing has transparent wall portions (14) for viewing visible patterns on the screen before recording with the camera, and the housing encloses a light source (24) for illuminating the screen.

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lying disorder such as a neoplasm, involved the remote sensing of the infrared radiation emitted from a scanned area. However, the sensing equipment developed to detect the emitted radiation produced thermographic outputs that erroneously indicated positive readings. Because 5 of the frequency of such false readings, the lack of agreement as to the results obtained made the procedure unacceptable. Furthermore, such electronic infrared sensing equipment is very expensive and requires the use of skilled personnel.

Independent of the work in the area of electronic infrared 10 thermography since 1968 there has been a substantial effort in laboratories throughout the world in developing display devices and temperature sensors using liquid crystals. These compounds, which conventionally are divided into three classes, namely, smetic, nematic, and cholesteric, possess one or more mesomorphic phases, intermediate between their solid crystal form and their isotropic form. In response 15 to subtle temperature changes the colorless isotropic form of cholesteric liquid crystals, due to their unique molecular structure, undergoes an optical transformation as it passes through the highly colored mesomorphic phase.

20 As an alternative to electronic infrared thermography researchers directed cholesteric thermotropism to the problem of visually viewing invisible radiation emitted from an object which falls within the infrared portion of the electromagnetic spectrum. Early disclosures such as contained in U. S. Patent No. 3,533,399 revealed a procedure 25 whereby a first layer most commonly comprising a black pigment and a second layer of cholesteric substances were applied to the skin area under investigation to produce visible thermal patterns that could be photographed. The impracticality of the time consuming procedure for mass screening and routine examination, the nonreusability of materials, the uneasiness of patients negated acceptance of the procedure. 30

In order to overcome the disadvantages inherent in the procedure of coating body areas with temperature responsive materials and their subsequent removal, nonuniformity of coatings, nonrecovery of materials, thermometric devices comprising liquid crystal materials 35 that scan a surface area to produce thermograms containing information pertaining to temperature variations over the scanned areas were dis-



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DEVICE FOR DETECTING, MEASURING, AND
RECORDING BODY THERMAL EMISSIVITY

Background of the Invention

1. Field of the Invention

The present invention relates generally to a device for detecting thermal differentials emanating from a body and for transforming such differentials to a visible representation for thermographic recording. More particularly, the invention relates to a combination of an elastomeric film containing temperature responsive cholesteric liquid crystals to locate and to convert surface areas of temperature gradients to color patterns and an imaging system for photographing such patterns.

2. Description of the Prior Art

Medical literature is increasingly demonstrating how thermal sensing devices and materials can aid in the diagnosis of disorders when correlated with an individual's clinical history, physical examination and other laboratory tests and in the study of physiological reactions to pharmodynamic substances such as immunological, hormonal and vasomotor drugs. The field of study involving the use of thermal sensing devices and materials, or thermography, may be defined as a process for detecting abnormal or diseased underlying conditions of an organism which produce temperature changes and for transforming these resulting thermal differentials emanating from such disorders or lesions to a visible display for photographic recording and analysis.

Early work, which was conducted to determine a methodology whereby elevated or so-called "hot areas", created by an infusion of an extraordinary number of blood vessels, may be indicative of an under-



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closed. U. S. Patent No. 3,847,139 is typical of such disclosures in which body contour garments, such as brassieres, incorporating temperature responsive substances produce thermal patterns that are observed and photographically recorded for comparative analysis. Due to differences of sizes and shapes of women's breasts, such garments are not satisfactory because they lack the conformability necessary to uniformly contact all of the scanned areas being investigated.

Disclosed as a process (particularly for the detection of mammary anomalies) that overcomes the inherent disadvantages of coating body areas with thermosensitive materials, or the use of flexible supports disposed against the surface under examination, or the utilization of supports called "thermosensitive pellicles with liquid crystals", U. S. Patent No. 4,060,654 teaches the use of a composite lamellar pellicle for producing photographable thermographic patterns by using liquid crystal materials applied to an inner sheet and sandwiched between two outer sheets which are enframed to preserve the planar shape. By using a temperature responsive series of pellicles containing different admixtures of liquid crystal materials, the practitioner can determine the thermal topography of a body regardless of the ambient temperature. However, because the pellicles are mounted in rigid rectangular frames, the device is conformability restricted in that it cannot be used on curved surface areas. Furthermore, lamellar pellicle thermography and the interpretation of thermograms is limited to clinical research facilities, hospitals, and doctors offices; being unsuited for direct use by the patient in her home.

In order to overcome the conformability limitations of thermoresponsive fabric brassieres and lamellar pellicles, a brassiere-like apparatus, as disclosed in U. S. Patent No. 4,135,497, provides liquid crystals interposed between flexible sheets to form a composite film. Conformance of the film to the contours of the body is attained by evacuation of air between the film secured in place by means of a pair of elastic straps encircling the women's chest and the body surface. The heat emitted by tissues of the various regions are transformed by the film into color patterns or thermograms which may be photographically recorded. However, the excessive time consuming special techniques to ensure body conformity tends to obviate the apparatus as a



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practical procedure for mass screenings and routine examinations. Apparatus bulk and complexity preclude its use to the more sophisticated medical facilities, and narrow thermoresponsive range composite film limit the application of a film to a particular tissue region.

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Summary of the Invention

The present invention provides a device for detecting thermal differentials emanating from a radiant source by transforming such differentials to visible representations that can be photographically recorded for subsequent diagnostical and analytical study. The device 10 is generally frustum-of-a-pyramid-shape, relatively pressure tight, partially transparent, two handle-grip enclosure having a contour-conformable, thermoresponsive screen and a specially designed photographic system to record resultant thermochromatic patterns. A practitioner grasps the handle-grips and places the temperature sensitive 15 end into contact with the body area under study, for example, the breasts of a female. The resulting thermogram that appears on the thermoresponsive screen is observed by the practitioner by peering through the top transparent wall of the device. By pressing a button located in the handle-grips the photographic system is activated and 20 the thermogram is recorded. The ability to view a body area before photographic recordation enables the practitioner to scan the general area under study to select the most meaningful thermograms for recording.

It is therefore an object of the present invention to provide 25 a device for detecting and measuring body thermal emissivity which is capable of providing a photographic record of high resolution thermographic display of a small temperature change occurring at any point within a relatively broad temperature range over a various portion of a body.

30 It is a further object of the invention to provide a device for detecting, measuring, and recording body thermal emissivity for use in the early detection of cancer or of other contralateral heat differentials in the body due to various abnormal or disease conditions or to monitor chemotherapy or progress of surgical recovery.

35 Still another object of the invention is to provide a device for detecting, measuring, and recording body thermal emissivity which



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is so designed and constructed that such device may be easily and conveniently used for mass screenings and routine examinations by persons with limited special training or skills and without complicated or expensive equipment or support apparatus or carefully controlled environmental conditions.

Yet another object of the invention is to provide a sanitary method whereby thermographic data can be conveniently and permanently recorded for regular periodic comparative thermal analysis extending over long periods of time at low cost.

Achievement of the above and other objects and advantages which will be apparent from a reading of the following disclosure and overcoming of shortcomings and disadvantages of prior art devices have preceded in the case of the present invention from the discovery by the instant inventor that records of good resolution of precise and readily distinguishable chromatic changes in response to relatively small temperature changes over a relatively broad temperature range may be achieved by the use of conformably designed and specially constructed reusable liquid crystalline systems affixed to a suitable thin, elastic substrate to be held in contact with an area of surface to be investigated.

Brief Description of the Drawings

For a further understanding of the nature and objects of the invention, reference should be had to the detailed description of the exemplary embodiments taken in connection with the appended drawings in which:

FIG. 1 is a perspective view of a device constructed in accordance with this invention showing a practitioner at the back or practitioner end of the device holding the front or patient end of the device against the upper torso of a female by means of a pair of handle-grips and viewing the area under examination through the transparent window that forms a portion of the top side of the device.

FIG. 2 is a front perspective view of the device shown in FIG. 1 to particularly illustrate a thermoresponsive screen, the pair of handle-grips, and a camera for processing color film.

FIG. 3 is a cross sectional view of the device taken along the line 3-3 of FIG. 2 particularly illustrating a portion of a photo-



graphic system and the normally at-rest thermoresponsive screen affixed to bellows as depicted with unbroken lines. FIG. 3 also illustrates a female breast which shapes the thermoresponsive screen as depicted with the broken lines.

5 FIG. 4 is a top planar view of the device in accordance with this invention particularly illustrating a pair of internally housed flash lamps of the photographic system, right and left handle-grips with a pair of switches to activate the photographic process, and the thermoresponsive screen with a body fitting bellows affixed to the
10 support housing of the device.

FIG. 5 is a fragmentary cross sectional view of the device looking forward along with line 5-5 of FIG. 4 particularly illustrating a thermogram displayed on the thermoresponsive screen and one of the handle-grips with a trigger.

15 FIG. 6 is an elevational view of the device looking forward along the line 6-6 of FIG. 3 particularly illustrating a thermogram displayed on the thermoresponsive screen and a data display showing patient pertaining information.

FIG. 7 is an enlarged elevational view of the patient information strip illustrated in FIG. 6.
20

FIG. 8 simulates an actual simultaneous "instant-print" photograph of the thermogram and data display illustrated in FIG. 6.

25 FIG. 9 is a perspective view of an embodiment of a device in accordance with the invention having a thermoresponsive screen affixed to the front or patient end of the device and a temperature and humidity controlled recirculating air supply.

FIG. 10 is a fragmentary cross sectional view of the thermoresponsive screen of this invention.

Description of the Preferred Embodiments

30 Referring to FIG. 1, a thermal emissivity device 10 of this invention is held against the upper torso of a patient 11 by a practitioner 12 by means of a pair of handle-grips 13 affixed to device 10. A portion of the top and side walls 14 of device 10, which is generally frustum-of-a-pyramid shaped, is constructed with transparent material
35 in order that the interior of device 10 can be illuminated with ambient light. Ambient illumination of the interior of device 10 allows practi-



tioner 12 to observe the pair of breasts 15 shown on a thermoresponsive screen 16 which comprises an encapsulated liquid crystal thermoresponsive material system affixed to an elastomeric substrate, hereinafter described in greater detail. The normally concave configuration of 5 thermoresponsive screen 16 is shaped by the pair of breasts 15 making intimate thermal contact with the thermoresponsive material system.

Heat differentials which may be created by an infusion of an extraordinary number of involved blood vessels into any of the breast area are transformed by the thermoresponsive material system into a 10 color display discernible by practitioner 12. After viewing the display, if practitioner 12 decides that a permanent record is required, provided in the pair of handle-grips 13 is a triggering mechanism 25, particularly shown in FIGS. 3 and 4, that activates an internally housed photographic system. Referring to FIGS. 1-4, located rearwardly 15 within device 10 is camera 17 for recording color displays of thermoresponsive screen 16. Preferably camera 17, sold under the trademark Champ Kodamatic by Eastman Kodak Co., Rochester, New York, is inverted from the normally used position so that the color print is now automatically ejected upwards through exit slot 19 on the top side of device 10. In addition to cameras that produce color prints, cameras 20 that produce images on film or images on video screens can also be used.

Optical chamber 20, which is a portion of a device 10 defined by the four device walls, the sensitive side of thermoresponsive screen 16, and the lens side of camera 17, is relatively air tight in order 25 to eliminate deleterious materials including film processing chemicals and medical vapors. Rearwardly housed within optical chamber 20 for sharper focusing is an accessory lens 21 axially located approximately 18 inches from thermoresponsive screen 16 and capable of covering an active screen area of about 9 inches by 13 inches. Thermoresponsive screen 16 is affixed to conformable rim 18 by means of an adhesive, flexible clamp, elastic band, or any combination thereof and conformable rim 18 is held in place onto optical chamber 20 by means of a snap or a high friction joint 22 which allows easy interchanging of various 30 conformable rims. The body fitting conformable rim 18 may be constructed from elastomeric, plastic, or paper materials suitable for accordian folds or from closed cell compressible foam. As previously indicated 35



when device 10 is pressed against the upper torso of a patient 11, thermoresponsive screen 16 conforms to the shape of breasts 15 (shown by the broken lines in FIG. 3) simultaneously causing portions of thermoresponsive screen 16 not in contact to breasts 15 to bulge outwardly 5 of device 10.

Referring to FIGS. 3 and 4, housed in optical chamber 20 are: rearwardly and downwardly of thermoresponsive screen 16 is data strip 23 which appears in the field of view of lens 21; rearwardly of data strip 23 and on the floor of optical chamber 20 are two commercially available illumination assemblies 24 each having a flash lamp and front surface diffuser lens; rearwardly of illumination assemblies 24 is power supply 27 and cover clip 29 to secure power supply 27 to device 10; and electrical cables 26 interconnecting the triggering mechanism 10 and camera 17 and power supply 27, and high voltage wires 28 inter- 15 connecting illumination assembly 24 and power supply 27. Forming a rearward vertical wall of optical chamber 20 is camera adjustable mounting plate 31 which is integrally part of and is used to axially align camera 17 with thermoresponsive screen 16. Except for lens 21 camera 17 is located outside optical chamber 20 in a compartment formed by 20 the camera adjustable mounting plate 31, back plate 32, and the four outer walls of device 10. After an exposure is processed, a photographic record 34 is ejected through film exit slot 19 in film pack door 30 of camera 17.

Referring to FIGS. 5-8, if practitioner 12 decides that a 25 color pattern 33 appearing on thermoresponsive screen 16 should be photographically recorded, while holding handle-grips 13, he merely depresses button 25. However, before activating the photographic process, practitioner 12 enters patient pertaining information into data strip display 23 by means of a conventional keyboard which may be located 30 at back plate 32 or remote from device 10. Typical keyboard entered information comprises a file no. (social security number), the time a color pattern was photographed (minute, hour, day, month, and year), the temperature of optical chamber 20 (cam°), patient's body temperature determined by a reference thermometer (ref°), a reference temperature of thermoresponsive screen 16 (scr°), and an indication mark that 35 the photograph is a full frontal view of the right (r) and left (l)



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breast or a side view of the right (r) or left (l) breast.

Referring to FIG. 9, a thermoresponsive plate 41 comprising a flexible rim and a thermoresponsive screen is held in place onto device 10 (as shown in FIG. 3) by means of a snap or a friction joint which allows easy interchanging of a series of thermoresponsive plates that range from 26°C. to 38°C.. Preparation of the thermoresponsive plates 41 containing encapsulated liquid crystalline esters 2-50 microns in diameter are formed and composed as described in the application of George T. Brown, Jr., et al., Ser. No. 404,506, filed August 2, 1982. 10 Also in this embodiment of the instant invention temperature and humidity controlled air is supplied to the internal portion of device 10 through tube 36 and is exhausted through tube 37. Cable 35 supplies power to device 10 from an external source in lieu of battery power supply 27. In order to maintain thermoresponsive screen 16 and sanitary and free of deleterious external substances, a 4-7 mil plastic film, preferably polyester, is placed over thermoresponsive plate 41 15 and is held in place by a flexible rim slightly larger than the rim affixed to device 10.

Referring to FIG. 10, thermoresponsive screen 16 of this invention comprises a 4-8 mil elastomeric substrate 38, for example, a polyurethane or a polyisoprene rubber sheath such as can be obtained from the Hygenic Corporation, Akron, Ohio, onto which is affixed about a 2 mil black layer 39 and a 4-6 mil layer 40 of encapsulated liquid crystals. Acrylic rubber added to the admixtures of layers 39 and 40 increases the elastic properties of these layers and make them more compatible with elastomeric substrate 38. Preparation of the admixtures of layers 39 and 40 are described in the application of George T. Brown, Jr., et al. Ser. No. 509,933, entitled THERMOGRAPHIC INDICATOR OVERLAY.

While the within invention has been described as required by law in connection with certain preferred embodiments thereof, it is to be understood that the foregoing particularization and detail have been for the purposes of description and illustration only and do not in any way limit the scope of the invention as it is more precisely defined in the subjoined claims.

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CLAIMS

1. A device for detecting and recording the thermal emissivity of a body, comprising a substantially rigid housing defining a chamber and having opposite forward and rearward end portions, a flexible thermal responsive screen adapted to conform to the contour 5 of the body and having a coating of liquid crystals effective to transform thermal differentials emanating from the body to visible color patterns, means for mounting said screen on said forward end portion of said housing, means including a camera for recording the image of the patterns, means mounted on said rearward end portion of said housing 10 for supporting said camera, means for supplying air to said chamber to produce pressurized air within said chamber outwardly against said screen, and said housing having transparent wall means providing for viewing the color patterns on said screen prior to recording the image of the patterns with said camera.
2. A device as defined in 1 wherein said housing has tapering walls causing said forward end portion to be larger than said rearward end portion, and said flexible screen is removably connected to said forward end portion.
3. A device as defined in claim 2 wherein said housing has a frusto-pyramid configuration.
4. A device as defined in claim 1 wherein said transparent wall means include transparent opposite side wall portions connected by a transparent top wall portion to provide for said viewing the patterns.
5. A device as defined in claim 1 wherein said means for supplying air to said chamber comprise means defining a passage within said housing for directing pressurized air into said chamber, and said means for mounting said screen and for supporting said camera form generally airtight seals with said housing.
6. A device as defined in claim 1 wherein said housing has opposite sidewalls with means for manually gripping and supporting said housing with said screen in a generally vertically position.



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7. A device as defined in claim 6 wherein said means for gripping and supporting said housing comprise a pair of handle members projecting laterally outwardly from said opposite sidewalls of said housing.

8. A device as defined in claim 1 wherein said means for mounting said screen on said housing comprise a generally rectangular frame, and means for releasably attaching said frame to said housing.

9. A device as defined in claim 8 wherein said frame is resilient for conforming to contours of the body.

10. A device as defined in claim 8 wherein said means for releasably attaching said frame to said housing provides for conveniently interchanging different said screens having different coatings of liquid crystals corresponding to different temperature ranges.

11. A device as defined in claim 1 wherein said housing comprises a rearward wall disposed generally parallel to said screen and having an opening therein, and said camera includes a lens member projecting through said opening.

12. A device as defined in claim 1 wherein said camera comprises a self-developing camera having means for ejecting a print of the recorded image laterally outwardly from said rearward portion of said housing.

13. A device as defined in claim 1 and including means for positioning a data display adjacent said screen for recording by said camera along with the image of the patterns on said screen, and said data display is positioned for viewing through said transparent wall means.

14. A device as defined in claim 1 and including light means confined within said housing and disposed for directing light onto said screen.



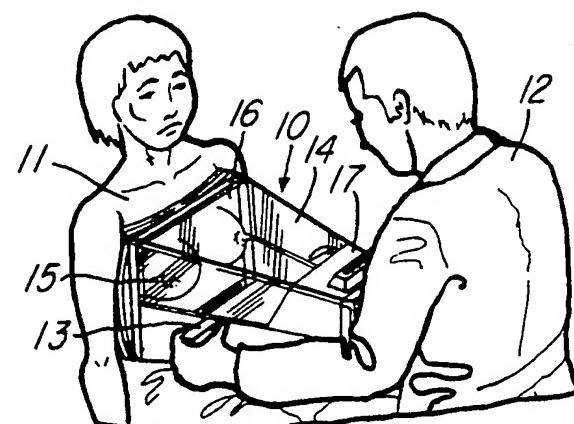
-12-

15. A device as defined in claim 1 wherein said chamber is relatively air tight.

16. A device as defined in claim 1, wherein the thermoresponsive screen comprises a 4-6 mil layer of 2-50 microns diameter encapsulated liquid crystals affixed to about a 2 mil black layer, said black layer affixed to a 4-8 mil elastomeric substrate.



FIG-1



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FIG-2

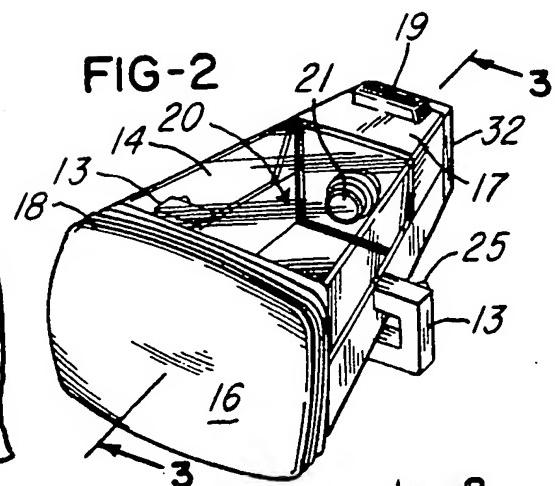


FIG-3

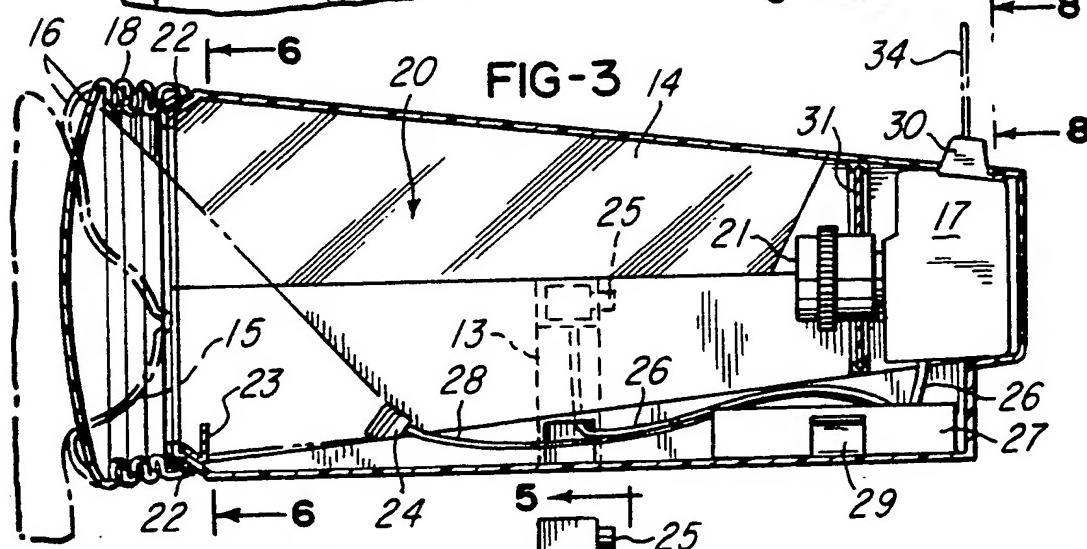
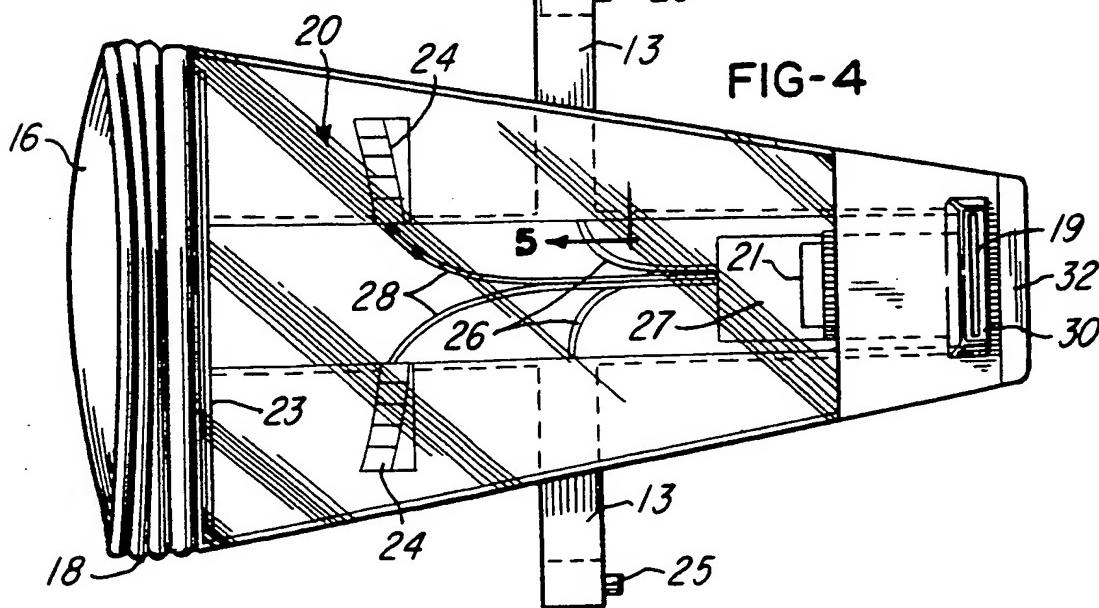
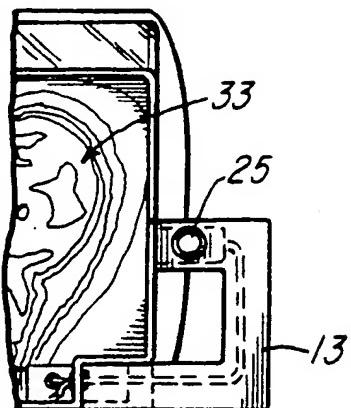
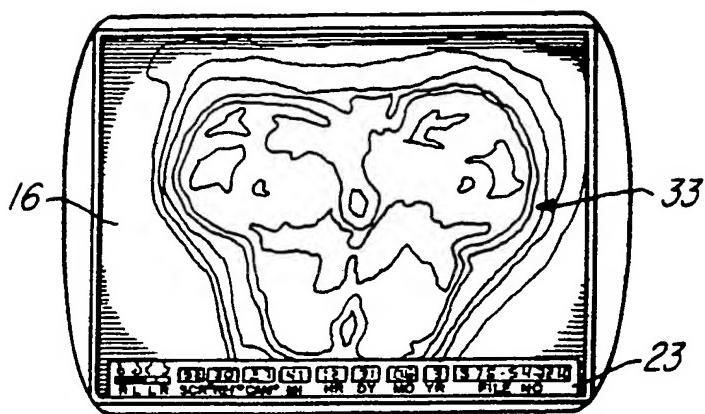
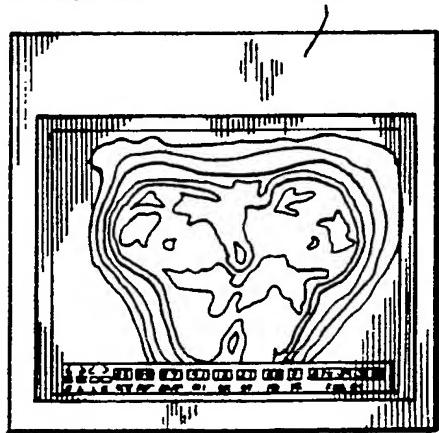
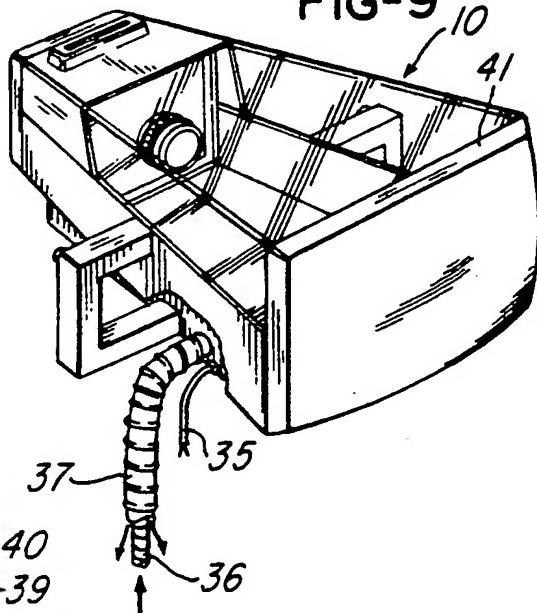
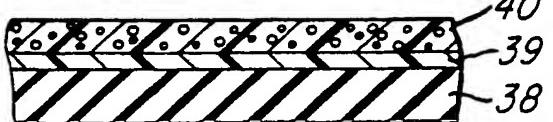


FIG-4



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FIG-5**FIG-6****FIG-7****FIG-8****FIG-9****FIG-10**

INTERNATIONAL SEARCH REPORT

International Application No. PCT/US84/01098

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)³

According to International Patent Classification (IPC) or to both National Classification and IPC
 INT. CL. 3 A61 B 5/00
 U.S. CL. 128/738

II. FIELDS SEARCHED

Minimum Documentation Searched⁴

Classification System	Classification Symbols
U.S.	128/736 354/18,81,293
Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched ⁵	

III. DOCUMENTS CONSIDERED TO BE RELEVANT¹⁴

Category ⁶	Citation of Document, ¹⁵ with indication, where appropriate, of the relevant passages ¹⁷	Relevant to Claim No. ¹⁸
X	US, A, 3,533,399	13 October 1970 GOLDBERG et al
X	US, A, 4,358,189	09 November 1982 NYLANDER
A	US, A, 4,135,497	23 January 1979 MYERS et al
A	US, A, 3,918,810	11 November 1975 COHEN
A	US, A, 4,327,743	04 May 1982 KATZ
A	FR, A, 2,452,910	05 December 1980 BOUTON

- Special categories of cited documents:¹⁵
- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier document but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search¹⁹

13 August 1984

Date of Mailing of this International Search Report²⁰

1984

International Searching Authority²¹

ISA/US

Signature of Authorized Officer²²

E.M. Coven

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